CHAPTER 2

Methodology and Modeling Approach

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Overall Methodology

Steps to define habitat suitability functions involved first identifying key indicator species or landscape features, then determining which hydrologic variables best quantified impacts to the selected species. Then, relationships between the hydrologic variables and the species were quantified, verifying these relationships where possible. System-wide simulation models were used to generate hydrologic information used as input to the habitat suitability relationships. Output from the relationships was expressed as time-series or long-term average values, depending on the indicator, and were obtained for multiple locations (model grid cells) or averaged over the domain of the model. In some cases, relationships were combined to provide a composite, or overall, indicator value or a series of values. The following sections describe the steps in obtaining habitat suitability indices in more detail and provide some information about the models chosen to generate hydrologic data for this study.

Identifying Indicators

The first step in this process of defining habitat suitability functions was to identify the principal indicator species or landscape features that would serve as a surrogate for the entire ecosystem in specific regions of the Everglades. In this study we chose six different indicators of ecosystem condition. Three indicators were landscape-scale features that vary over space but not significantly over the simulated thirty-year time. The landscape-scale indicators, namely ridge and slough landscape, tree islands, and periphyton, were considered functions of hydrologic conditions over long periods of time, on the order of decades. Two of the selected indicators, fish and alligators, varied over time and space. One indicator, wading birds, varied only over time. The wading birds habitat suitability index is not dependent on location as long as sufficient suitable habitat is available within the overall region. The selected indicators are illustrated in **Figure 2-1**.

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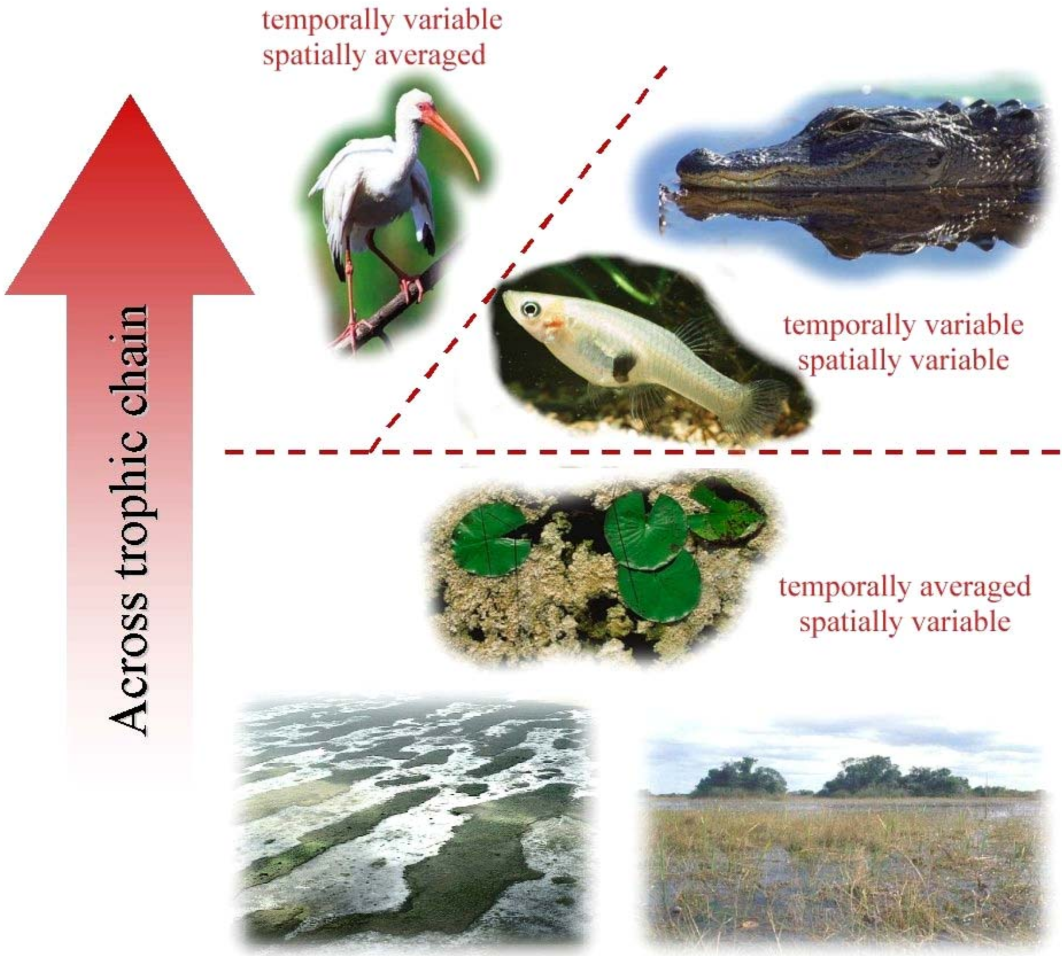

Figure 2-1. Indicator features of the Everglades selected for this study and their relative position across the trophic chain.

Identifying Applicable Area

The pre-drainage Everglades was not uniform throughout; different areas had different ecological and hydrologic characteristics. An important second step therefore was identifying the predrainage extent or "footprint" of each indicator species or feature. This was necessary to ensure that the indices would follow a central tenet of Everglades restoration: areas are to be restored as close to their original condition as possible.

Determining Hydrologic Variables

Following identification of the indicator feature or species and its applicable area the next step was to determine which hydrologic variables, attributes, or characteristics affect the selected indicator features or species. These hydrologic variables were functions of what is managed (i.e., water depths, flows, and hydroperiods) and the rates of change in these variables. Variables may apply only in particular time periods and particular locations, in the same way as individual ecosystem indicators have an applicable area. Correct determination and quantification of the specific hydrologic variable or stressor that affects the ecosystem indicator is critical in quantifying the habitat suitability index. Hydrologic variables ranged from simple, such as long-term hydroperiod (time of ponding), which was used for periphyton, to complex, such as the rate of change of water depth within a certain time window relative to the depth of water, which was used for wading birds. Examples of hydrologic variables include the following:

- Water Depth
    - average (weekly, monthly, annual, between specified dates)
    - minimum, maximum, above/below thresholds
    - relative to depths at earlier dates
    - rates of recession
- Flow Direction
- Flow Velocity
- Hydroperiod
    - duration between specific dates (discontinuous, continuous)
    - time since last dry period
    - period below/above specified thresholds

Each of the above examples can be measured in the field, albeit some with difficulty at regional scales. They also can be simulated using hydrologic models. Their values are influenced by water management policies. The actual variables used for specific habitat suitability indices may be functions or combinations of those examples just listed. For example, wading bird habitat suitability indices may depend not only on the water depth and its drawdown rate in a specific period but also on the habitat suitability index value of a species of fish. The fish habitat suitability value may in turn depend on the hydroperiod durations of several previous years. The next section illustrates the methodology used to define habitat suitability functions for the particular species we selected.

Defining Habitat Suitability Functions

Once the specific hydrologic variables were selected for each species or feature of interest, the next step required identifying the relationship between those variable values (or the values of functions of multiple hydrologic variables) and the relative conditions of the indicator species or topographic features. Such a function is shown in **Figure 2-2**. These functions were based on observed data and the knowledge of those who were involved in this study. Once defined, these habitat suitability index functions were combined in various ways to obtain an overall ecosystem suitability value associated with any particular water management scenerio. **Figures 2-2** and **2-3** illustrate this procedure. Once such habitat suitability functions were defined, they were used together with time series of hydrologic values to create a time series of habitat suitability values, as shown in **Figure 2-3**.

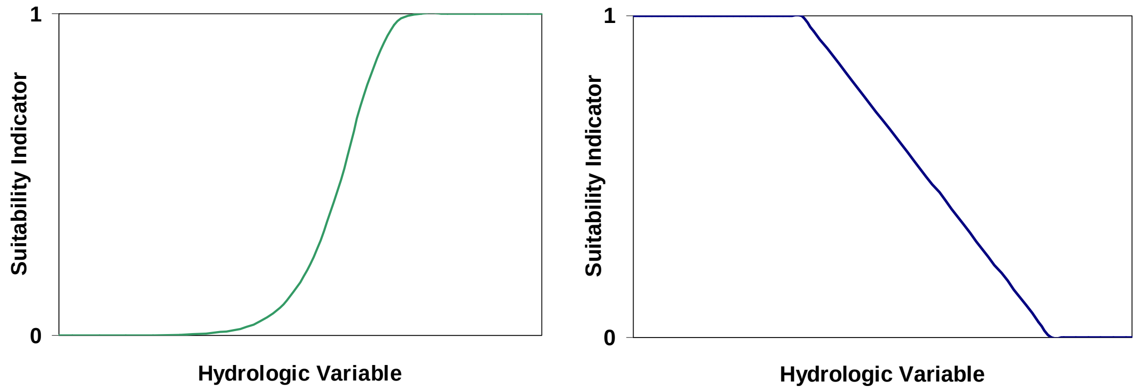

Figure 2-2. Two performance suitability indicators expressed as functions of hydrologic variables.

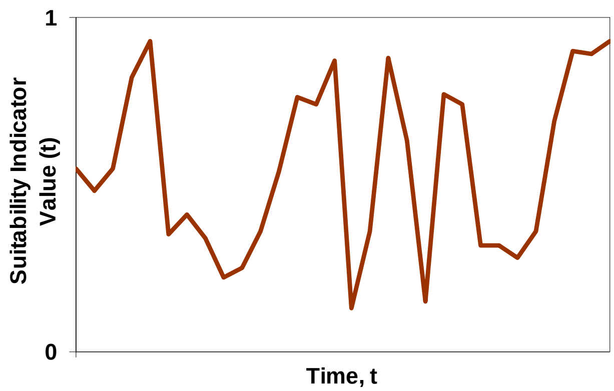

Figure 2-3. A time series of values of a suitability indicator derived from a time series of hydrologic variable values mapped into a habitat suitability indicator function such as shown in **Figure 2-2**.

Thus, the time series of suitability indicator values, shown in **Figure 2-3**, is a function of the time series of hydrologic variable values generated from a model simulation of a particular management plan or policy. These time series were characterized using various statistical measures including the following:

- Mean value
- Variance
- Reliability based on a specified threshold value
- Resilience based on a specified threshold value
- Vulnerability in duration or extent, again based on specified threshold value

Composite value based on time series values of multiple suitability functions were obtained various ways whether over time, as shown in **Figure 2-4**, or over space. The best way differed for the different indicators. Geometric means, weighted arithmetic means, and maximum or minimum values were used to obtain composite performance indicator values. The methods selected for combining different habitat suitability functions for the same ecosystem feature or species were determined during the calibration procedure.

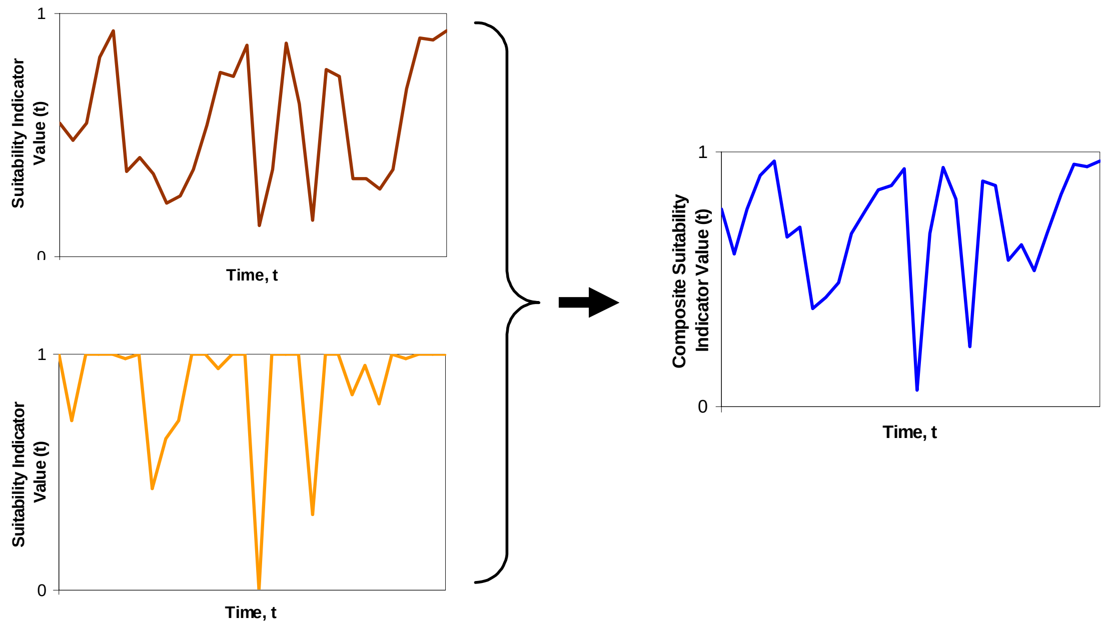

Figure 2-4. Creating a composite suitability indicator time series from multiple suitability indicator time series.

In addition to the specific statistical measures mentioned above, individual or composite suitability indicator time series values were summarized graphically or pictorially in a variety of ways. One way that defined and plotted probability of exceedance functions is shown in **Figures 2-5** and **2-6**. The areas under such functions are the mean suitability values.

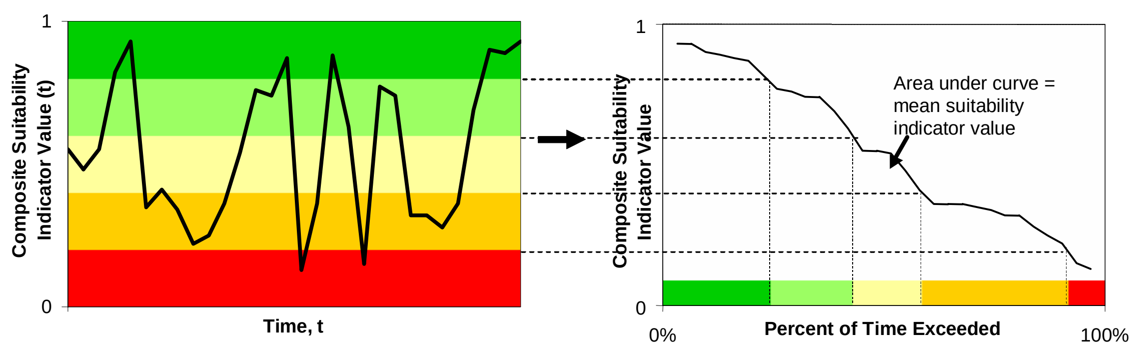

Figure 2-5. Establishing color-coded zones of indicator values for subsequent statistical analyses.

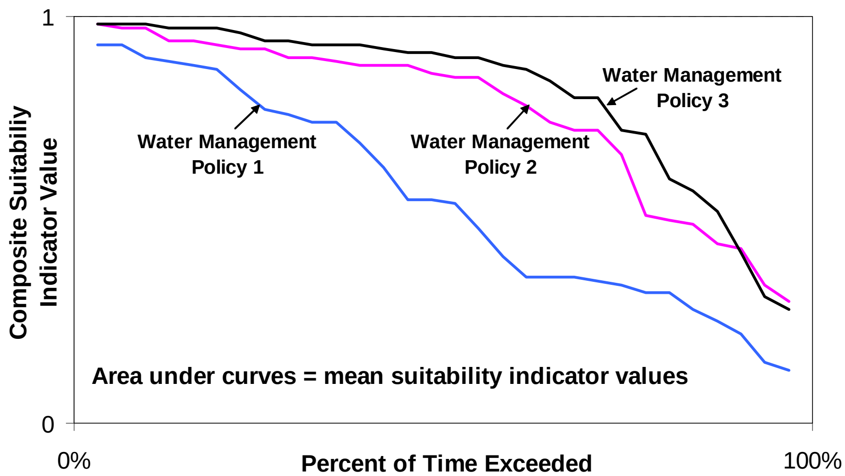

Figure 2-6. Exceedance functions for a particular composite suitability indicator under three different water management policies. The difference between the mean values is a measure of relative impact of different management alternatives.

In addition, color-coded maps were used to show ranges of suitability values over space at specified times. These are particularly useful in highlighting the challenge of creating a habitat that is perfect for all species at all times over the entire Everglades region. Ecology, at least in the Everglades, is in part about who is eating whom, and the condition of those being eaten is affected by the condition of those who are doing the eating!

For this study, we identified the hydrologic variables affecting the six selected ecosystem features and species: ridge and slough topography, tree islands, periphyton (algae), fish, alligators, and wading birds (**Figure 2-1**). Also estimated were the functions relating those hydrologic variables to the relative condition of the indicator. Multiple functions for the same indicator were then combined in ways that best corresponded to the observed data or expert judgment during the calibration procedure. It is important to notice that the functions developed for different ecosystems have different levels of complexity and have been subject to different degrees of calibration and verification. Although many of these functions will continue to improve over time, this exercise demonstrates one relatively simple way to obtain preliminary answers to questions involving trade-offs between water management or restoration plans and costs and ecological habitat impacts.

The next six chapters describe in more detail this process for the six specific indicators. These chapters are ordered starting from landscape (space-dependent) habitat suitability indices to biotic (space- and time-dependent) habitat suitability indices and moving across the trophic chain (**Figure 2-1**). Suitabilities for ridge and slough, tree islands, and periphyton are time-averaged but spatially-variable. Suitability for fish and alligators are spatially- and temporally-variable. Suitability of wading birds varies in time and is not dependent on location as long as sufficient suitable habitat is available within a larger area.

Hydrologic data or output from any model can be used as input to the habitat suitability indices. The most widely used regional hydrologic models in South Florida are the South Florida Water Management Model version 3.5 (SFWMM) and the Natural System Model version 4.5 (NSM). These models were used to simulate the alternatives on which the Comprehensive Everglades Restoration Plan (CERP) was based, and are also used in weekly and monthly operational planning for the operation of the Central and Southern Florida (C&SF) Project. Output from these models has been automated and processed into hundreds of different performance measures, and future automation of habitat suitability indices using output from the SFWMM and NSM is feasible. Hence, the SFWMM and NSM were selected as the models for producing hydrologic output on which to base the habitat suitability indices in this study.

The habitat suitability indices described here could be applied to other regional hydrologic models as well. Results from applying the habitat suitability indices to model output from the natural (NSM), current (1995 Base, SFWMM), and restored system (D13RNov98, SFWMM) simulations are presented on the next six chapters. A performance measure set comparing these runs can be found on the Restudy Modeling web page at http://www.sfwmd.gov/org/pld/restudy/hpm/ (see September 21, 2001 posting under "What's New" section). More details on the SFWMM and the NSM are given in the next section.

South Florida Water Management Model

The SFWMM is an integrated surface water-ground water model that simulates the hydrology and management of the South Florida water resource system from Lake Okeechobee to Florida Bay (**Figure 1-1**). Major components of the hydrologic cycle, including rainfall, evapotranspiration, overland flow, ground water flow, canal flow, and seepage beneath levees, are simulated. Additionally, the model simulates the operations of the C&SF Project components including major wellfields in the developed lower east coast, impoundments, canals, pump stations, and other water control structures. The ability to simulate various hydrologic scenarios under natural conditions using the NSM (**Figure 2-7a**) and under current conditions using the SFWMM (**Figure 2-7b**) facilitates the investigation of trade-offs between different water supply, flood control, and environmental demands in various subregions. The models have been calibrated and verified using water level and discharge measurements at hundreds of locations distributed throughout the region within the model boundaries. Documentation (SFWMD 1999), including model calibration, verification, and peer review, can be viewed at http://www.sfwmd.gov/org/pld/hsm/models/sfwmm.

The model uses a daily time step, consistent with the minimum time increment for which input climatic data are available and can be simulated for time periods ranging from one month to 36 years. A distributed, finite-difference modeling technique is used to model the gridded portion of the model domain with 2-mile by 2-mile square grid cells. Lumped parameter modeling approaches are used for Lake Okeechobee and the northern lake service areas, which include the Caloosahatchee and St. Lucie basins. Homogeneity of physical and hydrologic characteristics are assumed within each grid cell. The grid

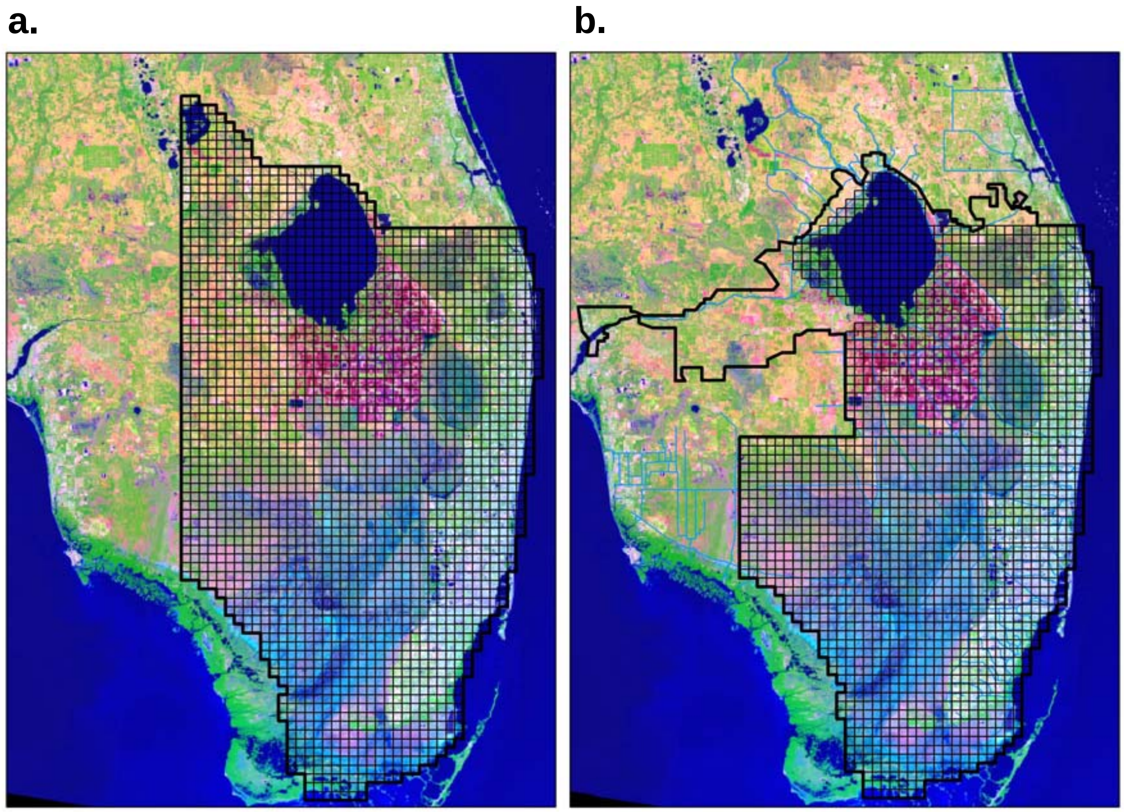

Figure 2-7. Domain and grid for a) NSM and b) SFWMM.

discretization in the SFWMM is sufficiently fine to describe the solution to the overland and ground water flow equations with reasonable resolution and to minimize numerical errors (Lal 1998).

In the version of the SFWMM (version 3.5) used in this study, primary dynamic inputs are daily rainfall and evapotranspiration available for the period from 1965 to 1995, which includes both drought and wet periods. Rainfall is estimated from more than 600 stations within the model domain and reference crop evapotranspiration is calculated using the Penman-Monteith method (Monteith 1965) with climatic data from 12 stations. Static inputs include physical parameters such as land elevation, land use, soil properties, aquifer properties, basin definitions, irrigation information and utility demands. The preponderance of the SFWMM code is dedicated to mimicking the complex operational rules that regulate flow into and out of canals and water storage areas. Current or proposed policies and rules for flood control, water supply, and environmental restoration or enhancement are specified in the input. Typically, alternative plans are compared against baseline conditions specified in the model input.

Output from the SFWMM is available in text and binary formats and include several summaries and water budgets. Postprocessing utilities are used to produce extensive sets of performance measure graphics and tables comparing selected SFWMM simulations for alternative water management strategy comparisons.

Natural System Model

The NSM was derived from the SFWMM using the same algorithms as the SFWMM and, where possible, calibrated SFWMM model parameters. The NSM (SFWMD 1998) differs from the SFWMM in that it does not simulate the influences of any man-made features and uses estimates of presubsidence topography and predevelopment vegetation cover. The NSM simulates a predrained hydrologic response of the system to the same climatic inputs as the SFWMM, allowing for meaningful comparisons between the modeled response of the managed system and the natural (predrained) system.

It is difficult to determine how closely the NSM resembles the actual predrainage system because predrainage measurements corresponding to NSM simulated output are either nonexistent or not directly comparable. Two sources of uncertainty are associated with model input; estimated predrainage topography and hydraulic resistance. The NSM uses calibrated current system hydraulic resistance values from the SFWMM. The absence of present day analogs for predrainage vegetation and the presence in the current system of large areas with little or no flow contribute to the uncertainty of these values. Comparison of NSM output with an extensive historical study of predrainage hydrology (McVoy et al. in review), indicates that simulated water depths appear generally to be shallower than those compiled in the historical study; simulated annual variation (rise and fall) of water depths appears to be smaller than historical; and simulated spatial pattern of water depths is different. The shallower depths and smaller range may be related to a combination of the 1965-1995 period of weather data being drier than the long-term average and possibly to under simulation of inputs from Big Cypress and Lake Okeechobee. The differing spatial patterns may be related to the assumed predrainage topography.

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